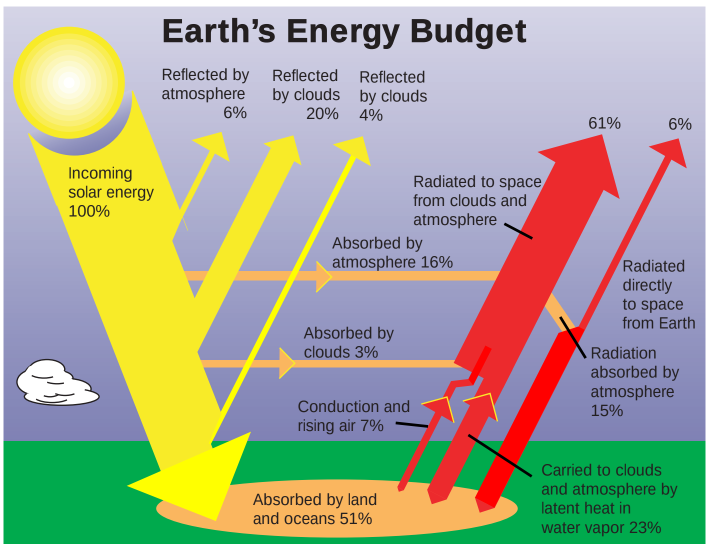
Measuring Solar Radiation Incident on Earth

Solar Constant–3 (SOLCON–3)

Life on Earth is possible because the climate conditions on Earth are relatively mild. One element of the climate on Earth, the temperature, is determined by the heat exchanges between the Earth and its surroundings, outer space. The heat exchanges take place in the form of electromagnetic radiation. The Earth gains energy because it absorbs solar radiation, and it loses energy because it emits thermal infrared radiation to cold space.



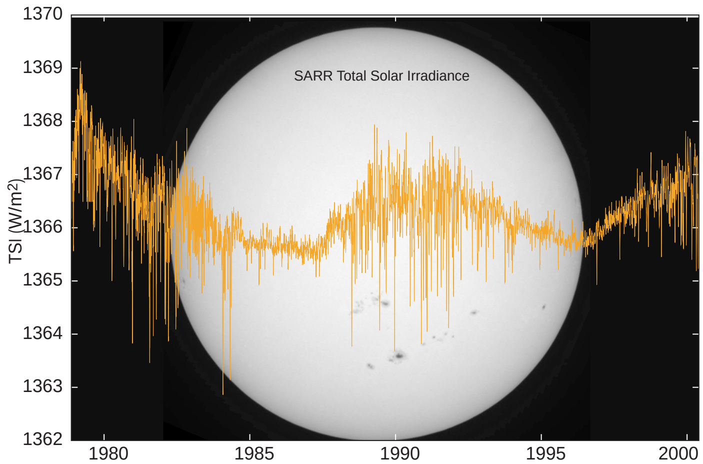
Earth gains energy through solar radiation and loses energy through thermal infrared radiation lost to space. The balance between energy gains and losses determines the temperature on Earth.

The heat exchanges are in balance: the heat gained by the Earth through solar radiation equals the heat lost through thermal radiation. When the balance is perturbed, a temperature change and hence a climate change of the Earth will occur.

One possible perturbation of the balance is the CO_2 greenhouse effect: when the amount of CO_2 in the atmosphere increases, this will reduce the loss of thermal infrared radiation to cold space. Earth will gain more heat and hence the temperature will rise.

Another perturbation of the balance can occur through variation of the amount of energy emitted by the sun. When the sun emits more energy, this will directly cause a rise of temperature on Earth.

For a long time scientists believed that the energy emitted by the sun was constant. The "solar constant" is defined as the amount of solar energy received per unit surface at a distance of one astronomical unit (the average distance of Earth's orbit) from the sun. Accurate measurements of the variations of the solar constant have been made since 1978. From these we know that the solar constant varies approximately with the 11-year solar cycle observed in other solar phenomena, such as the occurrence of sunspots, dark spots that are sometimes visible on the solar surface. When a sunspot occurs on the sun, since the spot is dark, the radiation (light) emitted by the sun drops instantaneously. Oddly, periods of high solar activity, when a lot of sunspot numbers increase, correspond to periods when the average solar constant is high. This indicates that the background on which the sunspots occur becomes brighter during high solar activity.



Variation of the solar constant with time since 1978. The variation has a of period of approximately 11 years. The downward spikes correspond to the occurrence of dark sunspots which mark the height of the solar cycle. Some dark sunspots are visible on the background image of the sun.

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Background Information

Science

To know the influence of the sun on climate changes on Earth, it is necessary to make long-term, accurate measurements of the solar constant. The most accurate measurements can be made from space, thus avoiding perturbations by Earth's atmosphere. A number of instruments to measure the solar constant have been flown since 1978 on satellites. Each of these satellite instruments has a limited lifetime. As the different instruments measure a different mean level of the solar constant, and as their measurements have to be combined into one single time series of the solar constant, a common reference, the Space Absolute Radiometric Reference (SARR), has been defined. It provides, for each individual instrument, a SARR adjustment coefficient to bring all the different instruments to the same mean level.

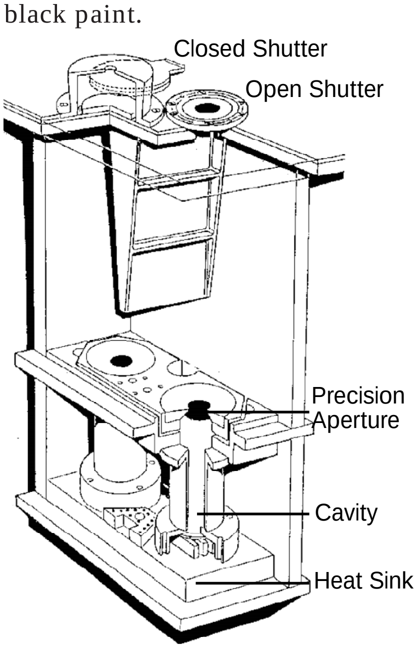
Why measure solar constant from orbit?

- SOLCON measures the solar irradiance from space to avoid perturbations by the atmosphere of the earth.
- SOLCON is used as a reference to construct a long duration time series of the solar irradiance.

The SOLCON instrument is a reference instrument for the measurement of the solar constant. It is flown regularly during short periods on the Space Shuttle. During shuttle flights SOLCON is used to determine the SARR adjustment coefficients of the satellite instruments that are active at the same time.

Instrument Principle

The SOLCON radiometer is the first differential absolute solar radiometer in space, developed at the Royal Meteorological Institute of Belgium. Basically solar radiation is measured through absorption in a cavity covered with black paint.

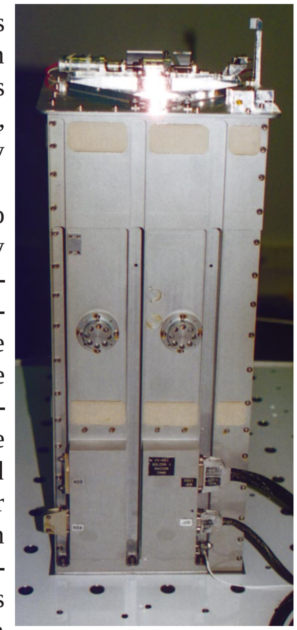


The central elements of SOLCON are a pair of blackened cavities on a common heatsink. Sunlight is absorbed in a cavity when the shutter in front is opened.

The SOLCON radiometer's core is formed by two blackened cavities constructed side by side on a common heat sink. In between each cavity and the heat sink a heat flux transducer is mounted. The difference between the two transducers' outputs gives a differential heat measurement. This measurement principle is analogous to a household pair of scales which give a differential measurement of weight.

Both cavity channels are equipped with a shutter in front to block or admit light to the cavity. In the open shutter phase, solar radiation flows into the cavity through a precision aperture and is absorbed. Besides the heating of the cavity by the sun, the cavity can be heated electrically trough a resistor.

Equilibrium between the two cavity heat fluxes is maintained by a regulating servo system. In the default measurement sequence a constant electrical power is fed into one cavity, the "reference" cavity, while its shutter remains closed. The electrical power in the other cavity, the "measurement" cavity, is regulated continuously, while its shutter sequentially opens and closes (both open and close phases take 90 seconds). When the instrument is pointed at the sun, the equilibrium electrical power in the measurement cavity drops proportionally to the absorbed solar power when going from the closed to the open phase.

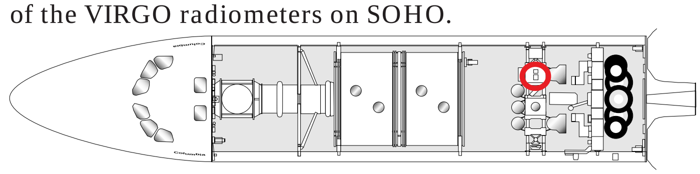


SOLCON–3 radiometer unit sitting atop FREESTAR. The digital processor unit is out of view to the right.

Accurate electrical power measurements are obtained by separate measurement of the voltage over and the current through both cavity heating resistors. The basic measurement of the solar radiative flux is proportional to the drop in the measurement cavity electrical power divided by the precision aperture area.

Earlier Results

The SOLCON type instrument flew on the space shuttle on Spacelab 1 (1983), the Atmospheric Laboratory for Applications and Science missions — ATLAS 1 (1992), 2 (1993), and 3 (1994) — and on Hitchiker missions as SOLCON–1 (1997) and –2 (1998). During this last mission, SOLCON was used to determine the SARR adjustment coefficients of the Variability of Solar Irradiance and Gravity Oscillations (VIRGO) radiometers on the Solar Oscillation and Heliospheric Observatory (SOHO) satellite, and to verify the SARR adjustment coefficients of the Active Cavity Radiometer Irradiance Monitor (ACRIM 2) and Earth Radiation Budget Satellite instruments. During its flight on Fast Reaction Experiments Enabling Science, Technology, Applications and Research (FREESTAR), SOLCON will be used to determine the SARR adjustment coefficient of the ACRIM 3 instrument, and to verify the stability of the SARR adjustment coefficients of the VIRGO radiometers on SOHO.



Approximate location of this payload aboard STS–107.

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